A GUIDE TO THE SAN DIMAS EXPERIMENTAL FOREST

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A GUIDE TO THE SAN DIMAS EXPERIMENTAL FOREST

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Cover: Upper left, Bell small watershed No. 4; upper right, Raingage Hill at Tanbark Flat; lower left, San Dimas lysimeter installation; lower right, streamgaging station, Intermediate watershed No. III.

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THE SAN DIMAS EXPERIMENTAL FOREST

Watershed Areas

Watershed	Drainage area Square miles	Acres	Range in elevation
		MAJOR	
San Dimas	15.75	10,080	1500-5500
Big Dalton	4.46	2,855	1700-3500
		INTERMEDIATE	
San Dimas			
I Wolfskill	2.39	1,530	1700-5200
II Fern	2.14	1,370	2600-5500
III Upper East Fork	2.14	1,370	2600-5200
IV East Fork	5.48	3,510	1900-5500
V North Fork	4.23	2,710	1900-4500
VI Main Fork	13.14	8,410	1600-5500
VII West Fork	1.72	1,100	1600-3100
Total XII (San Dimas)	15.75	10,080	
Dalton			
VIII Bell	1.36	870	1900-3500
IX Volfe	1.16	740	1900-3500
X Monroe	1.37	875	1800-3400
Total XI (Dalton)	4.46	2,855	
		SMALL	
Bell			
No. 1	0.121	77	2500-3400
No. 2	0.158	100	2500-3500
No. 3	0.097	62	2500-3400
No. 4	0.058	37	2500-3100
Total	0.434	276	
Fern			
No. 1	0.055	35	4500-5400
No. 2	0.063	40	4500-5400
No. 3	0.084	53	4500-5400
Total	0.202	128	

SAN DIMAS EXPERIMENTAL FOREST

WATER PROBLEMS IN SOUTHERN CALIFORNIA

Water is generally recognized as the most important factor affecting the existence and future growth of the great metropolitan, agricultural, and industrial developments in southern California.[1/] The phenomenal growth of this region in 60 years, indicated by an increase in population from 217,000 in 1890 to 5,700,000 in 1950, has brought about serious problems of which water supply and flood regulation are paramount.

Natural conditions of climate, topography, and vegetation contribute to the severity of local water problems. Most of the region is hot and dry from May to October and subject to intense rains in other months. Rugged mountains that rise abruptly near populated and highly developed valleys are sources of floods that have caused extensive damages downstream. Brush, also known as chaparral, is the dominant vegetation on the mountains below elevations of about 5,000 feet. Open coniferous forests form the principal cover at higher elevations. During the summer seasons the vegetation, especially the chaparral, becomes very inflammable. When mountain watersheds are denuded by fire the magnitude of floods from them is sometimes greatly increased.

Water Supply Problems

Early settlers in southern California obtained water from streams and springs whose sources were the nearby mountains. Needs for greater supplies were met by digging shallow wells, some of which produced artesian flows, and by developing water-collecting tunnels and small storage reservoirs in the foothills. Later the growing demands for water made it necessary to sink deeper wells in the valleys to reach water tables lowered by the increased draft upon them. Continuing overdraft in recent years has lowered the water tables near the coast and permitted sea water intrusion in certain basins, with resultant loss of usable water. In some other localities curtailment of water use has been necessary, particularly during periods of low rainfall.

Growing water needs led to importation of water into southern California, starting in 1913. Aqueducts have been built to bring water from the eastern slopes of the Sierra Nevada and from the Colorado River, each more than 250 miles distant. These developments, made at tremendous cost, are indicative of the value of water in a region where other natural advantages abound.

Southern California now contains about 50 percent of the State's population, but its streams carry only about 2 percent of the State's water supply. In 1950 southern Californians used more than $3\frac{1}{2}$ million acre-feet of water. About half of this amount was used for irrigation

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1/ Southern California is considered here to include the counties of San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, Riverside, San Diego, and Imperial, with a total area of 31,370,000 acres, or about 31 percent of the State of California.

in the Imperial and Coachella Valleys, and came from the Colorado River. About 70 percent of the water supply for the remainder of the region came from local watersheds. Although portions of southern California are supplied with imported water, supplies from the local mountains are relied upon in many areas.

Flood Regulation Problems

Southern California also has serious flood problems. Major floods caused by heavy winter rains usually carry large quantities of debris which greatly increases the difficulties and costs of flood regulation. This debris comes from the rugged and geologically unstable mountains where erosion of soil and rock is naturally severe. Flood flows, bulked with mud and rock, have caused losses of life, and property damages amounting to millions of dollars. Repeated experiences have shown that destruction of the vegetation on the mountains by fire may greatly increase surface runoff and erosion, thereby adding to the magnitude of floods and the damages done by them. Disturbance of the vegetation and soil by the construction of highways in the mountains also has accelerated erosion in some watersheds. Other serious consequences of floods are the siltation of reservoirs and the wastage to the sea of water that cannot be caught for use. Water-spreading, a method of replenishing underground supplies, cannot be done with flows carrying a debris load.

Downstream flood control works such as debris basins, reservoirs, large retarding basins, and channel improvements have been constructed by Federal and local agencies. More than 200 million dollars have been expended for these works. The completion of similar works that are planned will raise total expenditures for flood regulation in southern California to more than 500 million dollars.

Protection of Mountain Watersheds

Before 1892 foresighted leaders in southern California recognized the relationship of mountain watersheds to the water problem in this region. Through the efforts of these leaders several forest reserves were established between 1892 and 1907 for the primary purpose of protecting local watersheds to "insure favorable conditions of water flows" as well as the "preservation of timber for the use and necessities of citizens of the United States." These reserves later became the national forests of southern California, administered by the Forest Service of the U. S. Department of Agriculture. Thus, national recognition was given to the protection of about 3 million acres of public watershed lands in southern California.

Watershed Research

The need for information concerning the influence of watershed conditions upon water supply, floods, and erosion prompted the Forest Service to start preliminary studies in southern California about 40 years ago. The studies were continued by the California Forest and Range Experiment Station in 1927, soon after its establishment. The San Dimas Experimental Forest was set up as a center for watershed research in 1933, with the cooperation of the State of California, county and municipal agencies, conservation groups, water companies, engineers, and agriculturists.

SAN DIMAS EXPERIMENTAL FOREST

Monthly Climatic Data

Tanbark Flat Field Headquarters (Elevation 2,800 feet)

Month	Rainfall 24-year average	Evaporation 17-year[1] average	Air temperature[2] Absolute maximum		
			Absolute maximum	Absolute minimum	Mean
	------- inches -------		------- degrees -------		
October	1.2	5.8	102.0	25.5	60.5
November	2.1	3.9	87.0	29.0	53.8
December	5.7	2.5	84.5	21.5	49.1
January	4.9	2.4	80.5	18.0	46.2
February	6.0	2.4	82.0	22.0	46.7
March	4.8	3.5	80.0	24.0	48.8
April	2.4	4.2	88.0	29.0	53.4
May	0.5	5.9	99.0	28.5	57.3
June	0.1	7.1	101.0	34.0	62.6
July	T	10.1	104.0	39.0	71.5
August	0.1	10.1	106.0	38.0	72.2
September	0.3	8.4	107.0	37.5	69.5
Annual	[3]28.1	66.3	107.0	18.0	57.6

1/ Weather Bureau type evaporation pan.

2/ Air temperature for 19 years of record.

3/ 24-year average based on San Dimas Experimental Forest records 1933 through 1952, and Los Angeles County records for the 5-year period 1928 through 1932.

SAN DIMAS EXPERIMENTAL FOREST

Annual Climatic Data

Tanbark Flat Field Headquarters (Elevation 2,800 feet)

Year	Rainfall	Evaporation[1]	Air temperature: Absolute maximum	Absolute minimum	Annual mean
	------- inches	-------	------- degrees	-------	
1933-34	24.4		104.0	30.0	60.9
1934-35	34.8		96.0	25.0	56.8
1935-36	24.3	67.6	101.5	29.0	57.7
1936-37	43.8	67.9	98.0	19.0	57.9
1937-38	48.1	65.8	101.0	30.0	58.7
1938-39	27.0	72.6	100.5	22.0	57.8
1939-40	22.0	77.7	99.5	30.5	59.4
1940-41	48.2	61.4	95.5	32.0	58.1
1941-42	16.7	70.0	99.0	25.0	56.3
1942-43	45.2	70.1	101.5	26.5	58.1
1943-44	33.5	59.8	103.0	27.0	56.1
1944-45	29.7	59.9	97.0	26.5	55.3
1945-46	27.0	63.4	100.0	27.0	58.0
1946-47	27.6	63.5	100.5	27.0	58.3
1947-48	15.8	70.0	103.5	24.0	56.2
1948-49	16.9	64.7	100.0	18.0	54.5
1949-50	20.8	64.1	107.0	22.0	57.5
1950-51	11.5	72.4	102.0	23.0	59.6
1951-52	41.1	57.5	98.5	22.5	56.7
Average[2]	[3] 29.4	66.4	107.0	18.0	57.6

1/ Weather Bureau type evaporation pan.
2/ Annual average or range.
3/ 19-year average based on San Dimas Experimental Forest records.

THE SAN DIMAS EXPERIMENTAL FOREST

The San Dimas Experimental Forest covers 17,000 acres within the Angeles National Forest, and is situated on the southern slope of the San Gabriel Mountains in the San Dimas and Big Dalton drainages. Selection of the research area was based upon the following features: (1) It is representative of much chaparral-covered mountain land in southern California; (2) it is separated from the main San Gabriel Mountain mass by deep canyons which minimize the possibilities of underground water movement into the area; (3) the two major drainages contain a number of tributary watersheds of intermediate size, and many small watersheds, which can be studied; (4) the vegetation includes different chaparral associations as well as different ages of cover; and (5) the existence of San Dimas and Big Dalton dams, built and maintained by Los Angeles County Flood Control District, provides measuring controls for the major drainages.

Research Objectives

Watershed research on the San Dimas Experimental Forest, and related studies conducted elsewhere in southern California, have two broad objectives. The first is to determine how watersheds function: what happens to the precipitation, and how water and soil movement are influenced by conditions of vegetation, soil, geology, and topography. The second is to develop methods of watershed management that will ensure the maximum yield of clear, usable water with the minimum of flood runoff and soil erosion. Most research on the San Dimas area, thus far, has been directed toward the first objective.

Study of Watershed Functions

The following studies are designed to learn about watershed functions.

1. Climate--Climatic records, including air temperature, relative humidity, wind direction and velocity, and evaporation, have been collected at seven stations within the San Dimas Forest at altitudes ranging from 1,500 to 5,200 feet. Measurement of precipitation on the area was provided for originally by a network of 310 rain gages. Most of the gages were placed on contour trails. Supplementary studies were made to determine suspected errors in the rainfall sampling system. The results indicated that rain gages, tilted and oriented normal to watershed slopes, sampled the rainfall more accurately than the original network of vertical gages. Accordingly the first sampling system was replaced in 1950 with a network of 120 tilted gages. Fifteen gages in the new network are instruments which record both the amount and intensity of rainfall.

2. Streamflow--Measurements of runoff from the two major drainages are obtained from records of flow into San Dimas and Big Dalton reservoirs. These major watersheds have been divided into 10 tributary "intermediate watersheds" and contain two groups of small watersheds, the Bell and Fern series.

Each intermediate and small watershed contains a gaging station at its mouth. The gaging stations for the intermediate watersheds consist of three units--a 90-degree V-notch weir to measure low clear water flows; a steel San Dimas type flume to record ordinary storm flows that carry some

debris; and a large concrete flume to record high flood flows. Two of the large flumes are Parshall type structures, one contains a step-type gaging section of U. S. Geological Survey design, and seven are San Dimas type flumes. Stream gaging stations for the small watersheds consist of a V-notch weir and a San Dimas flume. All stations are equipped with continuously recording instruments. Difficulties encountered in measuring debris-laden flows made it necessary to develop the San Dimas flume. This type of flume has proven satisfactory for the measurement of such flows.

3. Watershed Erosion--Measurements of the amount of material eroded from the major watersheds are obtained by periodic surveys of sediments deposited in San Dimas and Big Dalton reservoirs. Measurements of material eroded from the Bell and Fern small watersheds are made in concrete-lined basins at the mouth of each watershed.

4. Surface Runoff and Erosion--Studies of surface runoff and erosion on slopes, as differentiated from entire watersheds, are being made on 1/40-acre plots. Each plot is equipped to record runoff synchronously with rainfall, and to catch all eroded mater al.

The nine Fern plots are situated on a 50 percent slope at an elevation of 5,000 feet in a cover of live oak. The vegetation had been unburned for more than 50 years prior to 1938 when a fire swept over this area. Surface runoff and erosion had been negligible before the vegetation was burned, but both were increased markedly for three years following the fire. After that the re-growing cover of native plants again protected the soil, and surface runoff and erosion became negligible.

The nine Tanbark plots are situated on a 35 percent slope at an elevation of 2,800 feet in a dense chaparral cover unburned since 1919. There has been practically no surface runoff or erosion on these plots. The brush was removed from six of the plots in 1952 and replaced with grass. Runoff and erosion measurements are being continued to study the effects of the vegetation change. In 1952 three more plots were established in a Coulter pine plantation near the Tanbark chaparral plots.

5. Evapo-transpiration--Evaporation of water from vegetation and soil, including that transpired by the plants, is being studied in soil-filled tanks called lysimeters. The San Dimas lysimeter installation near Tanbark Flat consists of 26 concrete tanks, each 10.5 x 21 feet in area and 6 feet deep, with surface and bottom slopes of 5 percent. These large lysimeters are augmented by more than 100 smaller metal tanks for supplementary studies. All are filled with a uniform mixture of local soil. One large lysimeter is kept bare, and several species of bunchgrass are planted in two others. Groups of from two to five other lysimeters are occupied by pure stands of five shrubs and Coulter pine, all native to these mountains. Runoff and seepage are caught and measured in tanks set in a concrete tunnel underground. Electric water level transmitters permit the rates of runoff and seepage to be recorded on clock-driven charts. Soil moisture at various depths in the lysimeters is measured frequently with electrical soil moisture instruments.[2] The

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[2] The fiberglas electrical soil-moisture instrument, developed on the San Dimas Forest, consists of a soil unit buried permanently at the point where moisture measurement is required, and a portable meter to measure electrical resistances of elements within the soil unit. Soil moisture and temperature are determined from these measurements.

measurements make it possible to determine water movement into and through the soil as well as evaporative losses from the soil and plants growing in the lysimeters.

To study effects of unnatural soil drainage and restricted root development upon the growth of plants and their use of water in the large "confined" lysimeters, additional records of surface runoff and soil moisture are obtained from five "unconfined" lysimeters. The latter consist of pits 17½ feet square and 7 feet, filled with lysimeter soil and planted to five of the species growing in the "confined" lysimeters.

6. Disposition of Rainfall--Studies were started in 1952 to determine the disposition of rainfall under covers of grass, brush, and pine. The work is being conducted on the 12 Tanbark runoff plots described above. Two series of electrical soil moisture units are installed in the center plot of each triplicate set, at regular depth intervals from 1½ inches to bedrock which, in some places, is more than 16 feet below the surface. These units and other instruments make it possible to determine the total precipitation reaching the soil, the quantities of surface runoff, infiltration, and evapo-transpiration, and the amount of precipitation which percolates through the soil to the underlying rock. The results obtained here will aid in future investigations concerning the management or change of vegetation on entire watersheds.

7. Physical Features--Inventories and maps have been prepared of the vegetation, soil, geology, and topography of the Forest. Analysis of streamflow and erosion data for each of the Forest watersheds is evaluating the influence of these physical features,and the climate, upon water flow and soil movement.

Study of Watershed Management

Studies of watershed management include tests of the following improvement measures.

1. Changes in Watershed Vegetation--Studies of rainfall disposition and soil movement on slopes under several types of vegetation have been started on the runoff plots described above. Behavior of the Bell and Fern small watersheds is being observed for a period of years, after which the vegetation on some of them will be changed. Measurements of water yield, flood runoff, and soil movement from the treated watersheds will then be compared with similar measurements made on the watersheds left undisturbed. Vegetation on the Fern watersheds had been unburned for more than 50 years prior to 1938 when a fire swept over this area. Records obtained before and after this accidental treatment showed that storm runoff and erosion were increased greatly for three years after the fire. Vegetation on the Bell watersheds has not been burned since 1919.

2. Management of Stream Bottom Vegetation--It is known that alders, willows, sycamores, and other plants found in stream channels use much water. Complete removal of this vegetation would eliminate water use by the plants, but the loss of shade would increase evaporation from the water and soil. Studies are to be made to determine the species and amount of vegetation that will result in the minimum loss of water from stream bottoms and still provide

bank protection during high flows. Some of the studies in this investigation will be conducted in lysimeters. Others will require altering the vegetation in stream channels where records of streamflow can be compared for periods before and after treatment.

3. Engineering Improvements--Studies are to be made of the effects of small dams and retaining walls built in stream channels on total streamflow yield and flood peaks, as well as the stability of soil and rock material in the channels and on adjacent slopes. Effects of the engineering improvements can be determined by comparing hydrologic records from treated and untreated watersheds before and after the improvements are made.

Corollary Watershed Research

Other Forest Service watershed studies have been completed or are in progress elsewhere in southern California. Among the completed studies are: (a) erosion control methods for mountain roads, (b) the "first aid" seeding of burned watersheds, and (c) an appraisal of flood and erosion damages resulting from watershed fires. Now in progress are studies of soil movement on watershed slopes and of vegetation treatment methods designed to reduce this movement. These studies are being carried on in cooperation with the California Institute of Technology in laboratories of that institution, and on field plots in the Los Angeles River watershed.

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Watershed research conducted on the San Dimas Experimental Forest is designed to serve the interests of many agencies, local, State, and Federal, and all others that are concerned with the management of wildlands in southern California for the production of usable water and prevention of damaging floods. Since many of the findings have application in other places, the work of the San Dimas Forest has values transcending its local benefits.

ANNOTATED BIBLIOGRAPHY OF PUBLICATIONS ON PHASES
OF WATERSHED MANAGEMENT RESEARCH ON THE
SAN DIMAS EXPERIMENTAL FOREST

January 1, 1953

Precipitation

An analysis of precipitation measurements on mountain watersheds, H. G. Wilm, A. Z. Nelson, and H. C. Storey. June 1939. Monthly Weather Rev. 67: 163-172.

Analysis was made of precipitation measurements from gage systems on mountainous watersheds to determine reliability of computed rainfall averages and to decide if the original gage distribution provided accurate sampling of the watershed rain catch. The requirements for accuracy of averages were modified in inverse relation to size and importance of storms. A simple average of well-distributed gage readings will agree within close limits with rain catch computed from isohyetal maps.

Topographic influences on precipitation, H. Storey. 1939. Pacific Sci. Cong. 6th, Berkeley, Stanford, and San Francisco, California. Proc. 4: Soil Resources 985-993. July 1941.

Isohyetal maps show distribution of annual precipitation successively State-wide, then over Los Angeles County, and finally in detail on the San Dimas Experimental Forest. Variations in precipitation are explained by reference to topographic influences.

A comparative study of rain gages, H. C. Storey and E. L. Hamilton. 1943. Amer. Geophys. Union Trans. Pt. I: 133-141.

Rainfall was caught in several types of rain gages placed on hillsides exposed in three different directions. Gage catches were compared with the catch of rain on adjacent large concrete surfaces laid parallel to and at ground level. Standard rain gage catch was found to be significantly closer to that of the ground surface if the gage was tilted normal to that surface rather than being exposed vertically.

#-Publications marked with (#) were available for distribution on January 1, 1953.

Rainfall-measurement as influenced by storm-characteristics in southern California mountains, E. L. Hamilton. 1944. Amer. Geophys. Union Trans. Pt. III: 502-518.

Preliminary records indicated the need for supplementary research on rainfall characteristics and storm behavior. From observations of 173 storms which produced 251 inches of rain over a 7-year period, a representative sample of 60 storms was subjected to detailed study. Records from a novel instrument, a "vectopluviometer" or directional rotating rain gage, permitted the development of directional storm patterns and computation of the angle of inclination of rainfall from the vertical which could be correlated with wind velocity and rainfall intensity. The study indicated that southern California storms follow definite patterns which can readily be classified into groups having definite characteristics. The interpretation of these group characteristics is necessary to determine the proper distribution and exposure of rain gages on mountain watersheds to insure the accurate measurement of precipitation.

A comparison of vertical and tilted rain gages in estimating precipitation on mountain watersheds, H. C. Storey and H. G. Wilm. 1944. Amer. Geophys. Union Trans. Pt. IV: 518-523.

Precipitation on a 100-acre watershed within the San Dimas Experimental Forest was measured with a network of rain gages at 22 sites. The gages were paired at each location, one being installed vertically and the other tilted normal to the slope. Analysis of a 4-year record showed that the better measure of total rainfall on this steep mountainous watershed was obtained by the use of the tilted gages.

A system for the synchronization of hydrologic records, E. L. Hamilton. 1943. Amer. Geophys. Union Trans. Pt. II: 624-631.

Describes how recording instrument charts on the San Dimas Experimental Forest are kept chronologically in step with each other by electrical time impulses sent hourly by a clock at the Tanbark Flat Field Headquarters. Several widely distributed tipping-bucket rain gages also record synchronously by sending electric impulses over similar circuits to a central laboratory where, after amplification through relays, rainfall increments of 0.02 inch are recorded on a strip chart having a separate space for each gage.

The San Dimas tipping-bucket rain-gage mechanism, E. L. Hamilton. February 1947. Amer. Met. Soc. Bul. 28(2): 93-95.

Description of an inexpensive mechanism for the measurement of rainfall intensities. The unit can be installed in a standard 8-inch rain gage and the rainfall rates transmitted electrically to a suitable recorder. Featured are frictionless and non-corrodible electrical contacts.

The problem of sampling rainfall in mountainous areas, E. L. Hamilton. 1949. (In Proc. Berkeley Symposium on Mathematical Statistics and Probability held August 1945 and in January 1946.) p. 469-475. University of California Press.

On the San Dimas Experimental Forest in southern California an extensive distribution of 200 rain gages was made to determine variations in amount of rainfall on different slopes and at different altitudes in connection with watershed management research. Preliminary analyses indicated that although the arrangement of the sampling units was adequate, the technique of measuring rainfall might be subject to question. A device called the "equivalent facet" was selected as the basis for revising the rainfall-sampling network. In this system the placement of the rain gages was adapted to the terrain on an areal basis.

Rainfall interception by chaparral in California, E. L. Hamilton and P. B. Rowe. 1949. U. S. Dept. Agr., Forest Service, in cooperation with Calif. Dept. Nat. Resources, Div. Forestry. 43 p., 16 illustrations.

Determination of rainfall not reaching the soil, called interception loss, is important in the solution of water supply and flood control problems. Loss of rainfall through interception by shrub type vegetation was measured at three locations in California. On one area in the Sierra Nevada foothills in central California 81 percent of an average annual rainfall of 42 inches reached the soil as throughfall and drip from the brush cover, 14 percent reached the soil as flow down the stems, and 5 percent was lost before reaching the soil as direct evaporation from the vegetation. On another area in the same vicinity with a different type of brush cover, 62 percent of an average annual rainfall of 38 inches reached the soil as throughfall, 30 percent as stemflow, and 8 percent was lost by interception. In the San Gabriel Mountains of southern California, 81 percent of an average annual rainfall of 22 inches reached the soil as throughfall, 8 percent as stemflow, and 11 percent was lost by interception. Amounts of throughfall, stemflow, and interception loss varied directly with storm size. However, the proportion of interception loss varied inversely with storm size. An equation of interception loss for storms of more than 0.3 inch is given for each study area. The interception process through the course of characteristic storms is discussed.

San Dimas rainfall and wind velocity recorder, E. L. Hamilton and L. A. Andrews. 1951. Amer. Met. Soc. Bul. 32(1): 32-33.

A vertical drum waterstage recorder was modified for operation with an electromagnetically operated pen. It is suitable for recording electrical impulses induced by tipping bucket rain gages or anemometers. The recorder will run for 8 days, and 75 lineal feet of impulses can easily be recorded on a 12 x 18 inch standard chart at a speed of 4-1/2 inches an hour.

Shock resistant lucite graduate, E. L. Hamilton, L. F. Reimann, and L. A. Andrews. September 1952. California Forest and Range Experiment Station Misc. Paper No. 9, 2 p., 1 figure.

Describes the construction of a durable plastic graduate designed to measure rain gage catch.

Streamflow

Measurement of debris-laden streamflow with critical-depth flumes, H. G. Wilm, John S. Cotton, and H. C. Storey. September 1938, Amer. Soc. Civ. Engin. Trans. 103(9): 1237-1278.

Field experiments were conducted for the purpose of adapting existing gaging stations to measurement of loaded flows. Several types of flumes were tested including a modification of the Parshall flume, trapezoidal flumes, and rectangular flumes with sloping floors. Following these experiments, a control flume of the third type was developed functioning as a broad crested weir in which water depths are measured at a point downstream of the "critical" section. Supercritical water velocities kept the flume scoured clean, and it thus could be rated to give greater accuracy of loaded streamflow than other existing devices.

A nomograph for the integration of streamflow records, Paul B. Johnson. October 1943. Civ. Engin. 13(10): 494-495.

The conversion of streamflow rates to total volume of water for given periods of time was facilitated by a nomograph which also contained a means for the ready determination of the decimal point.

Velocity-head rod calibrated for measuring stream flow, H. G. Wilm and H. C. Storey. November 1944. Civ. Engin. 14(11): 475-476.

The measuring stick described was developed to facilitate the gaging of small volumes of streamflow containing varying amounts of bed load and silt where standard measuring gages are not provided. It can be used even when the water carries considerable amounts of debris.

The San Dimas water-stage transmitter, E. A. Colman and E. L. Hamilton. June 1944. Civil Engin. 14(6): 257-258.

Description of water level indicating instrument designed by members of the Experimental Forest staff which has been used successfully on research installations for the measurement of liquid flow.

Instrument facilitates setting of weir zero values, Paul B. Johnson and Herbert C. Storey. November 1948. Civ. Engin. 18(11): 41-42.

The instrument described in this paper was designed for rapid and easy determination of the zero value on 90-degree V-notch weirs. A similar instrument could be used for weirs of different angles. It is simple to make, rugged, highly accurate, and requires little skill to use.

Geology

Geology of the San Gabriel Mountains, California, and its relation to water distribution, H. C. Storey. 1948. U. S. Dept. Agr., Forest Service, in cooperation with Calif. Dept. Nat. Resources, Div. Forestry. 19 p., 8 illustrations, colored map. (Separate maps available for distribution.)

Description of areal geology, structure, and history of the San Gabriel Mountains. Discussion of the manner in which geology influences the hydrology of a watershed from two viewpoints, (1) effect of land forms on the rainfall pattern, (2) the effect of structural fractures permitting water storage in rock formations, and the faults and dikes that determine the location of streams, springs, and underground basins.

\# <u>The dependence of field capacity upon the depth of wetting of field soils</u>, E. A. Colman. July 1944. Soil Sci. 58(1): 43-50.

Irrigation of field plots and subsequent soil moisture sampling is sometimes used to determine the field capacity, which is the maximum amount of moisture the soil can retain against drainage. This paper points out the errors which may arise from such determinations when based upon too shallow depths of penetration of the irrigation water.

\# <u>Some improvements in tensiometer design</u>, E. A. Colman, W. B. Hanawalt, and C. R. Burck. May 1946. Amer. Soc. Agron. Jour. 38(5): 455-458.

Description of a porous clay cup and manometer fittings for use in the study of water movement in the soil. Drawing of instrument.

<u>A laboratory study of lysimeter drainage under controlled soil moisture tension</u>, E. A. Colman. November 1946. Soil Sci. 62(5): 365-382.

A cylindrical column of soil 6 inches in diameter and 6 feet long was irrigated and drained four times, each time with a different moisture tension maintained at or beneath its base. The study showed it is possible to control seepage rate and the drained moisture content of a deep soil column by controlling the moisture tension maintained at the base of the soil.

<u>The place of electrical soil-moisture meters in hydrologic research</u>, E. A. Colman. December 1946. Amer. Geophys. Union Trans. 27(VI): 847-853.

Many kinds of hydrologic research can be facilitated by the use of direct reading electrical soil moisture meters. These meters can be used to measure accretions and losses of soil moisture and the direction and rate of soil-water movement, they can provide a means of controlling the time and amount of irrigation on crop land, and they can discern freezing and melting conditions of water in soil and snow. A meter has been developed by the California Forest and Range Experiment Station to meet these specifications.

\# <u>Manual of instructions for use of the fiberglas soil-moisture instrument</u>, E. A. Colman. October 1947. Revised June 1952. California Forest and Range Experiment Station. Multilithed. 20 p.

This manual gives a detailed description of the fiberglas and the ohmmeter units of the electrical soil-moisture instrument. The method of installation of the soil units, the method of using the ohmmeters, and the necessary steps in standardizing and calibrating the soil units are fully discussed.

\# <u>A laboratory procedure for determining the field capacity of soils</u>, E. A. Colman. April 1947. Soil Sci. 63(4): 277-283.

It was found that if small soil blocks were drained on a porous ceramic cell under a moisture tension of one-third atmosphere, the moisture retained in the blocks could be related empirically to the field capacity of the same soils determined under natural field conditions. A satisfactory degree of consistency was observed in the relationship between one-third atmosphere moisture percentage and field capacity. It is suggested that the procedure described may provide a convenient and rapid way of making an indirect determination of field capacity. Details of the design of the ceramic cell and moisture tension control equipment are given.

Soil surveying on wildlands: the problem and one solution, E. A. Colman. 1948. Jour. Forestry 46(10): 755-762.

Discussion of the difficulties involved in trying to make an intensive soil survey of a mountain watershed on the San Dimas Experimental Forest using the type of survey ordinarily conducted on agricultural lands. Description of a soil survey of the Angeles National Forest planned to classify and map wildland soils on the basis of their hydrologic characteristics.

The fiberglas electrical soil-moisture instrument, E. A. Colman and T. M. Hendrix. 1949. Soil Sci. 67(6): 425-438.

An instrument devised to measure soil moisture in place consists of a soil unit which includes a monel screen fiberglas cloth sandwich sensitive to soil moisture and a thermistor for temperature detection, and a meter unit which is a battery-powered alternating current ohmmeter. Relationships are indicated for (1) temperature-induced changes in resistance for various soils, (2) freezing and thawing in soils, and (3) moisture tensions. Soil moistures can be measured from pore-space saturation to well below the wilting point.

Calibration of fiberglas soil-moisture units, T. M. Hendrix and E. A. Colman. 1951. Soil Sci. 71(6): 419-427.

Units calibrated in field soil over a period of 15 months showed no indication of drift in relation between soil moisture content and soil unit resistance. Field and laboratory calibration are in good agreement when laboratory calibration is made in a natural soil core, whereas laboratory calibration made in granulated soil repacked to field apparent density does not agree with field calibration.

Ecology

The sample plot as a method of quantitative analysis of chaparral vegetation in southern California, Jerome S. Horton, October 1941. Ecology 22(4): 457-468.

In order to analyze quantitatively the density of vegetation occurring on a series of small chaparral-covered watersheds, 225 random milacre quadrats were measured. The data were segregated to show vegetative composition. Frequency distributions of vegetative densities were shown to be statistical curves other than normal. Size of plots had no significant influence on the results.

The wood rat as an ecological factor in southern California watersheds, Jerome S. Horton and John T. Wright. July 1944. Ecology 25(3): 341-351.

The wood rat is one of the most abundant rodents of the chaparral. With the exception of the heavy use of acorns at elevations above 4,500 feet the feeding habits of this animal do not exert any appreciable influence on chaparral cover because leaf and stem material, rather than seeds of the common chaparral shrubs, forms the bulk of its diet.

Stem surface area determination of nomograph, E. L. Hamilton. January 1949. Jour. Forestry 47(1): 57.

An alignment chart illustrated here cuts out many computations formerly needed for determination of the area of a vegetative stem.

Checklist of the vertebrate fauna of the San Dimas Experimental Forest, J. T. Wright and J. S. Horton, November 1951. California Forest and Range Experiment Station Misc. Paper No. 7. 15 p. Revision of 1946 mimeographed list.

The species comprising the vertebrate fauna of the San Dimas Experimental Forest are listed and very briefly discussed.

Trees and shrubs for erosion control in southern California mountains, Jerome S. Horton. 1949. U. S. Dept. Agr., Forest Service, in cooperation with Calif. Dept. Nat. Resources, Div. Forestry. 72 p.

The problem of erosion control planting in the mountains of southern California is discussed in this bulletin. Fifty-eight species of trees and shrubs are included and their place in erosion control outlined. A section is also included on methods of planting.

Effect of weed competition upon survival of planted pine and chaparral seedlings, J. S. Horton. June 1950. California Forest and Range Experiment Station Research Note No. 72. 6 p.

The effect of competition between annual plants and planted trees and shrubs was studied in 1944 on the San Dimas Experimental Forest in southern California. These plantings were made in an area adjacent to the San Dimas lysimeters to develop the proper method of establishing the desired vegetation. The study has shown that under conditions of summer drought, good survival of planted stock is dependent upon removal (at least during the first season) of competing annual grasses and herbs.

Plant Physiology

A rapid method of separating seed of chamise (Adenostoma fasciculatum) from the duff, E. C. Stone and J. Holt. January 1950. Ecology 31(1): 149.

In attempting to obtain large quantities of seed from the duff, various methods of separation by screening and floating were unsuccessful. A satisfactory procedure, making use of a small hand-operated "Clipper" seed separator, was worked out.

Water absorption from the atmosphere by plants growing in dry soil, E. C. Stone, F. W. Went, and C. L. Young. May 19, 1950. Science 111(2890): 546-548.

The ability of Coulter pine to survive long periods of drought on soils at or below the wilting point was investigated to determine the possibility of the plants taking up water from the atmosphere. A 2-year old Coulter pine seedling, growing in a sealed container to which no water had been added for 10 months, was sealed in a chamber which enclosed the vegetative portion of the plant and in which the initial humidity could be adjusted. Measurements with an Amico-Dunmore temperature-humidity sensing unit indicated a lowering of the humidity in the chamber from 98 to around 90 percent in 3 to 9 hours.

The effect of fire on the germination of the seed of Rhus ovata Wats, E. C. Stone and G. Juhren. 1951. Amer. Jour. Bot. 38(5): 368-372.

High temperature was found to be the factor responsible for fire-induced germination of seed of Rhus ovata. These temperatures rupture the second seed coat, which then allows water to reach the embryo causing the seed to germinate.

Evapo-Transpiration

\# The San Dimas lysimeters: instruments for evaluating the water economy of chaparral vegetation... Part 1--The lysimeter installation and research program. Part 2--The relative performance of four types of lysimeters, E. A. Colman and E. L. Hamilton. December 1947. California Forest and Range Experiment Station Research Note No. 47. 33 p.

The San Dimas lysimeters were established for the purpose of comparing the water economy of a number of chaparral plant species that are important in the management of southern California mountain watersheds. The installation includes five types of lysimeters and a climatic station located on an area of uniform topography. The same kind of soil has been used and uniformly placed in all the lysimeters in order to minimize soil variability. Rain, runoff, and seepage are measured, and weighing or periodic soil moisture sampling is used to study evaporative water losses. Comparisons of the soil water cycle, annual evapo-transpiration values, and yield of annual grass have been made between four types of lysimeters which are included in the San Dimas lysimeter installation. These lysimeters exhibit differences in depth, size, surface drainage, and seepage conditions. Some have been maintained bare, and some have supported stands of Bromus mollis.

Hydrology

\# Some aspects of watershed management in southern California, San Dimas Staff. April 1951. California Forest and Range Experiment Station Misc. Paper No. 1. 29 p.

Watershed management problems in southern California and the research program carried on by the California Forest and Range Experiment Station to aid in solving these problems are first discussed briefly. Second, the climate, geology, soils, and vegetation of the southern California mountains are described. Third, some of the results of the Station's hydrologic research are given.

\# Disposition of rainfall in two mountain areas of California, P. B. Rowe and E. A. Colman. December 1951. U. S. Dept. Agr. Tech. Bul. No. 1048. 84 p., 30 illus.

This publication reports a study seeking to evaluate and explain some of the hydrologic processes involved in the disposition of rainfall in two mountain areas. One area is near North Fork in the Sierra Nevada of central California, and one is in the San Dimas Experimental Forest in the San Gabriel Mountains of southern California.

The first part of the study was made on hillside plots in forest (ponderosa pine) and brush types of the two areas. These studies showed that annual burning of the vegetation cover, although reducing interception loss, did not appreciably affect total evaporation-transpiration loss. It did reduce the infiltration capacity of the soil, thereby increasing surface runoff. The reduced interception loss resulted in increased water yield (surface runoff plus seepage), but this increase was achieved by greatly increased surface runoff and erosion, and correspondingly reduced underground water yields. Removing the vegetation, trenching to prevent root intrusions, and maintaining a bare soil surface on the brush plots eliminated all interception and transpiration loss. Total evaporation loss was reduced but as in the case of annual burning, surface runoff and erosion was greatly increased.

During the long dry period of each summer, the bare soils lost appreciable quantities of water from all depths, but drying was slower and less complete in deep than in shallow soils. Total water yield was greatest from the plots with bare soil. However, underground yield was greatest from plots with natural vegetation.

The second part of the study was carried on in Monroe Canyon, a typical 875-acre brush-covered watershed of the San Dimas Experimental Forest. Average annual rainfall during the 2-year period of the study (1943-44 and 1944-45) was about 31.0 inches. Interception loss averaged about 2.4 inches per year and evaporation-transpiration, including riparian water loss, averaged 10.8 inches per year. Nearly 18.0 inches of rainfall was unaccounted for by the evaporative loss, but of this amount only about 4 inches appeared as streamflow. Thus more than three times as much water appears to have been yielded from the watershed as underground flow than as streamflow.

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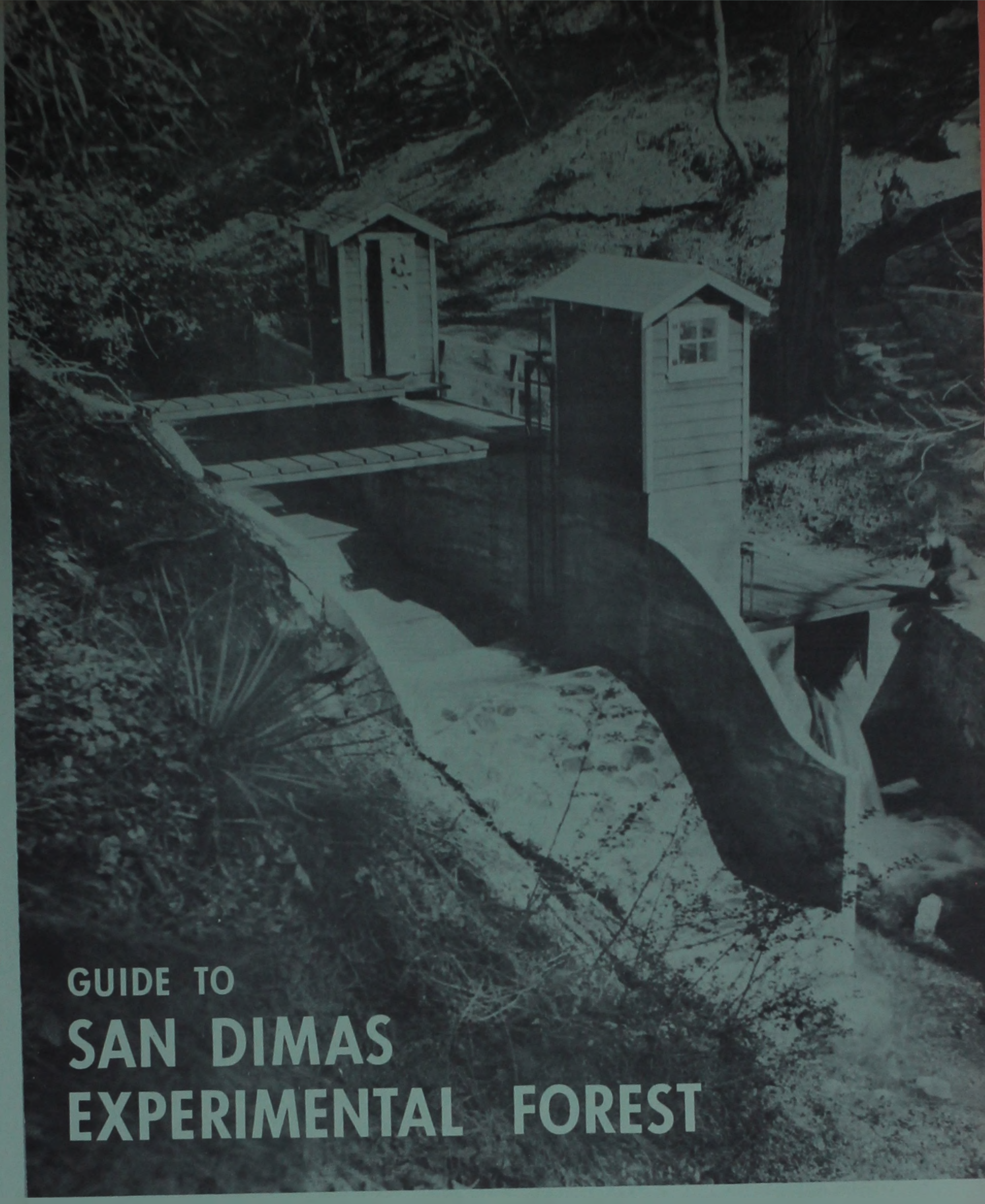

GUIDE TO SAN DIMAS EXPERIMENTAL FOREST

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

in cooperation with

DIVISION OF FORESTRY
DEPARTMENT OF NATURAL RESOURCES
STATE OF CALIFORNIA

SAN DIMAS EXPERIMENTAL FOREST

A GUIDE TO THE SAN DIMAS EXPERIMENTAL FOREST

By

J. D. Sinclair, E. L. Hamilton, and M. N. Waite

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WATER PROBLEMS IN SOUTHERN CALIFORNIA

Water is generally recognized as the most important factor affecting the existence and future growth of the great metropolitan, agricultural, and industrial developments in southern California.1/ The phenomenal growth of this region in 55 years, indicated by an increase in population from 321,000 in 1900 to more than 7,000,000 in 1955, has brought about serious problems of which water supply and flood regulation are paramount.

Natural conditions of climate, topography, and vegetation contribute to the severity of local water problems. Most of the region is hot and dry from May to October and subject to intense rains in other months. Rugged mountains that rise abruptly near populated and highly developed valleys are sources of floods that have caused extensive damages downstream. Brush, also known as chaparral, is the dominant vegetation on the mountains below elevations of about 5,000 feet. Open coniferous forests form the principal cover at higher elevations. During the summer seasons the vegetation, especially the chaparral, becomes very flammable. When mountain watersheds are denuded by fire the magnitude of floods from them is sometimes greatly increased.

Water Supply Problems

Early settlers in southern California obtained water from streams and springs whose sources were the nearby mountains. Needs for greater supplies were met by digging shallow wells, some of which produced artesian flows, and by developing water-collecting tunnels and small storage reservoirs in the foothills. Later the growing demands for water made it necessary to sink deeper wells in the valleys to reach water tables lowered by the increased draft upon them. Continuing overdraft in recent years has lowered the water tables near the coast and permitted sea water intrusion in certain basins, with resultant loss of usable water. In some other localities curtailment of water use has been necessary, particularly during periods of low rainfall.

Growing water needs led to importation of water into southern California, starting in 1913. Aqueducts have been built to bring water from the eastern slopes of the Sierra Nevada and from the Colorado River, each more than 250 miles distant. These developments, made at tremendous cost, are indicative of the value of water in a region where other natural advantages abound.

Southern California now contains about 55 percent of the State's population, but its streams carry only about 2 percent of the State's water supply. In 1950 southern Californians used more than 3-1/2 million acre-feet of water. About half of this amount was used for irrigation in the Imperial

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1/ Southern California is considered here to include the counties of San Luis Obispo, Santa Barbara, Ventura, Los Angeles, San Bernardino, Orange, Riverside, San Diego, and Imperial, with a total area of 31,125,000 acres, or about 31 percent of the State of California.

and Coachella Valleys, and came from the Colorado River. About 70 percent of the water supply for the remainder of the region came from local watersheds. Although portions of southern California are supplied with imported water, supplies from the local mountains are relied upon in many areas.

Flood Regulation Problems

Southern California also has serious flood problems. Major floods caused by heavy winter rains usually carry large quantities of debris which greatly increases the difficulties and costs of flood regulation. This debris comes from the rugged and geologically unstable mountains where erosion of soil and rock is naturally severe. Flood flows, bulked with mud and rock, have caused losses of life, and property damages amounting to millions of dollars. Repeated experiences have shown that destruction of the vegetation on the mountains by fire may greatly increase surface runoff and erosion, thereby adding to the magnitude of floods and the damages done by them. Disturbance of the vegetation and soil by the construction of highways in the mountains also has accelerated erosion in some watersheds. Other serious consequences of floods are the siltation of reservoirs and the wastage to the sea of water that cannot be caught for use. Water-spreading, a method of replenishing underground supplies, cannot be done with flows carrying a debris load.

Downstream flood control works such as debris basins, reservoirs, large retarding basins, and channel improvements have been constructed by Federal and local agencies. Approximately 300 million dollars have been expended for these works. The completion of similar works that are planned will raise total expenditures for flood regulation in southern California to more than 600 million dollars.

Protection of Mountain Watersheds

Before 1892 foresighted leaders in southern California recognized the relationship of mountain watersheds to the water problem in this region. Through the efforts of these leaders several forest reserves were established between 1892 and 1907 for the primary purpose of protecting local watersheds to "insure favorable conditions of water flows" as well as the "preservation of timber for the use and necessities of citizens of the United States." These reserves later became the national forests of southern California, administered by the Forest Service of the U. S. Department of Agriculture. Thus, national recognition was given to the protection of about 3 million acres of public watershed lands in southern California.

Watershed Research

The need for information concerning the influence of watershed conditions upon water supply, floods, and erosion prompted the Forest Service to start preliminary studies in southern California about 40 years ago. The studies were continued by the California Forest and Range Experiment Station in 1927, soon after its establishment. The San Dimas Experimental Forest was set up as a center for watershed research in 1933, with the cooperation of the State of California, county and municipal agencies, conservation groups, water companies, engineers, and agriculturists.

SAN DIMAS EXPERIMENTAL FOREST

Monthly Climatic Data

Tanbark Flat Field Headquarters (Elevation 2,800 feet)

Month	Rainfall 27-year average	Evaporation 20-year[1] average	Air temperature[2] Absolute maximum		
			Absolute maximum	Absolute minimum	Mean
	--- inches ---		--- degrees ---		
October	1.1	5.8	102.0	25.5	60.9
November	2.2	3.7	87.0	28.0	53.8
December	5.3	2.5	84.5	21.5	48.9
January	5.1	2.3	84.0	18.0	46.4
February	5.6	2.5	83.0	22.0	47.1
March	4.6	3.5	80.5	24.0	48.8
April	2.4	4.2	90.5	26.0	53.3
May	0.5	5.8	100.0	28.5	57.1
June	0.1	7.0	101.0	33.0	62.5
July	T	10.0	104.0	39.0	71.6
August	0.1	9.9	107.0	38.0	72.1
September	0.3	8.4	108.5	37.5	69.6
Annual	[3] 27.3	65.6	108.5	18.0	57.6

1/ Weather Bureau type evaporation pan.

2/ Air temperature for 22 years of record.

3/ 27-year average based on San Dimas Experimental Forest records 1933 through 1955, and Los Angeles County records for the 5-year period 1928 through 1932.

SAN DIMAS EXPERIMENTAL FOREST
Annual Climatic Data
Tanbark Flat Field Headquarters (Elevation 2,800 feet)

Year	Rainfall	Evaporation 1/	Air temperature: Absolute maximum	Air temperature: Absolute minimum	Air temperature: Annual mean
	----inches----		----degrees----		
1933-34	24.4		104.0	30.0	60.9
1934-35	34.8		96.0	25.0	56.8
1935-36	24.3	67.6	101.5	29.0	57.7
1936-37	43.8	67.9	98.0	19.0	57.9
1937-38	48.1	65.8	101.0	30.0	58.7
1938-39	27.0	72.6	100.5	22.0	57.8
1939-40	22.0	77.7	99.5	30.5	59.4
1940-41	48.2	61.4	95.5	32.0	58.1
1941-42	16.7	70.0	99.0	25.0	56.3
1942-43	45.2	70.1	101.5	26.5	58.1
1943-44	33.5	59.8	103.0	27.0	56.1
1944-45	29.7	59.9	97.0	26.5	55.3
1945-46	27.0	63.4	100.0	27.0	58.0
1946-47	27.6	63.5	100.5	27.0	58.3
1947-48	15.8	70.0	103.5	24.0	56.2
1948-49	16.9	64.7	100.0	18.0	54.5
1949-50	20.8	64.1	107.0	22.0	57.5
1950-51	11.5	72.4	102.0	23.0	59.6
1951-52	41.1	57.5	98.5	22.5	56.7
1952-53	15.5	61.5	105.0	25.5	57.7
1953-54	24.9	61.4	102.0	28.0	58.8
1954-55	19.9	61.4	108.5	24.0	57.3
Average 2/	3/ 28.1	65.6	108.5	18.0	57.6

1/ Weather Bureau type evaporation pan.

2/ Annual average or range.

3/ 22-year average based on San Dimas Experimental Forest Records.

THE SAN DIMAS EXPERIMENTAL FOREST

The San Dimas Experimental Forest covers 17,000 acres within the Angeles National Forest, and is situated on the southern slope of the San Gabriel Mountains in the San Dimas and Big Dalton drainages. Selection of the research area was based upon the following features: (1) It is representative of much chaparral-covered mountain land in southern California; (2) it is separated from the main San Gabriel Mountain mass by deep canyons which minimize the possibilities of underground water movement into the area; (3) the two major drainages contain a number of tributary watersheds of intermediate size, and many small watersheds, which can be studied; (4) the vegetation includes different chaparral associations as well as different ages of cover; and (5) the existence of San Dimas and Big Dalton dams, built and maintained by Los Angeles County Flood Control District, provides measuring controls for the major drainages.

Research Objectives

Watershed research on the San Dimas Experimental Forest, and related studies conducted elsewhere in southern California, have two broad objectives. The first is to determine how watersheds function: what happens to the precipitation, and how water and soil movement are influenced by conditions of vegetation, soil, geology, and topography. The second is to develop methods of watershed management that will ensure the maximum yield of clear, usable water with the minimum of flood runoff and soil erosion. Most research on the San Dimas area, thus far, has been directed toward the first objective.

Study of Watershed Functions

The following studies are designed to learn about watershed functions.

1. Climate--Climatic records, including air temperature, relative humidity, wind direction and velocity, and evaporation, were collected for several years at seven stations within the San Dimas Forest at altitudes ranging from 1,500 to 5,200 feet. Having thus established the local climatic pattern, records are being continued only at the Tanbark Flat field headquarters. Measurement of precipitation on the area was provided for originally by a network of 310 rain gages. Most of the gages were placed on contour trails. Supplementary studies were made to determine suspected errors in the rainfall sampling system. The results indicated that rain gages tilted and oriented normal to watershed slopes, sampled the rainfall more accurately than the original network of vertical gages. Accordingly the first sampling system was replaced in 1950 with a network of 120 tilted gages. This network in turn was reduced to 20 gages in 1954 following further analysis of accumulated data. Gages in the present rainfall sampling system are chiefly recording gages which supply both the amount and the rate of rainfall.

2. Streamflow--Measurements of runoff from the two major drainages are obtained from records of flow into San Dimas and Big Dalton reservoirs. These major watersheds have been divided into 10 tributary "intermediate watersheds" and contain two groups of small watersheds, the Bell and Fern series.

Each intermediate and small watershed contains a gaging station at its mouth. The gaging stations for the intermediate watersheds consist of three units--a 90-degree V-notch weir to measure low clear water flows; a steel San Dimas type flume to record ordinary storm flows that carry some debris; and a large concrete flume to record high flood flows. Two of the large flumes are Parshall type structures, one contains a step-type gaging section of U. S. Geological Survey design, and seven are San Dimas type flumes. Stream gaging stations for the Bell and Fern small watersheds consist of a V-notch weir and a San Dimas flume. Difficulties encountered in measuring debris-laden flows made it necessary to develop the San Dimas flume. This type of flume has proven satisfactory for the measurement of such flows.

As of 1954 continuous records of streamflow are being taken for only six of the intermediate watersheds. The four discontinued stations, however, were equipped with instruments to indicate maximum streamflow peaks.

3. Watershed Erosion--Measurements of the amount of material eroded from the major watersheds are obtained by periodic surveys of sediments deposited in San Dimas and Big Dalton reservoirs. Measurements of material eroded from the Bell and Fern small watersheds are made in concrete-lined basins at the mouth of each watershed.

4. Surface Runoff and Erosion--Studies of surface runoff and erosion on slopes, as differentiated from entire watersheds, are being made on 1/40-acre plots. Each plot is equipped with a trough to catch surface runoff and eroded material, and some record runoff synchronously with rainfall.

The nine Fern plots are situated on a 50 percent slope at an elevation of 5,000 feet in a cover of live oak. The vegetation had been unburned for more than 50 years prior to 1938 when a fire swept over this area. Surface runoff and erosion had been negligible before the vegetation was burned, but both were increased markedly for three years following the fire. After that the regrowing cover of native plants again protected the soil, and surface runoff and erosion became negligible.

Measurements of runoff and erosion also are being obtained from other plots in connection with studies of rainfall disposition.

5. Disposition of Rainfall--Studies were started in 1952 to determine the disposition of rainfall under covers of grass, brush, and pine. The work is being conducted on five triplicate sets of plots at Tanbark Flat. Twelve plots are situated on slopes of approximately 35 percent at an elevation of 2,800 feet in a dense chaparral cover unburned since 1919. The brush was removed from six of the plots in 1952 and replaced with grass. At that time three more plots were established in a Coulter pine plantation near Tanbark Flat.

Three series of electrical soil moisture units are installed in the center plot of each triplicate set, at regular depth intervals from 1-1/2 inches to bedrock which, in some places, is more than 16 feet below the surface. These units and other instruments make it possible to determine the total precipitation reaching the soil, the quantities of surface runoff, infiltration, and evapo-transpiration, and the amount of precipitation which percolates through the soil to the underlying rock. The results obtained here will aid in future investigations concerning the management or change of vegetation on entire watersheds.

6. Evapo-transpiration--Evaporation of water from vegetation and soil, including that transpired by the plants, is being studied in soil-filled tanks called lysimeters. The San Dimas lysimeter installation near Tanbark Flat consists of 26 concrete tanks, each 10.5 x 21 feet in area and 6 feet deep, with surface and bottom slopes of 5 percent. These large lysimeters are augmented by more than 100 smaller metal tanks for supplementary studies. All are filled with a uniform mixture of local soil. One large lysimeter is kept bare, and several species of bunchgrass are planted in two others. Groups of from two to five other lysimeters are occupied by pure stands of five shrubs and Coulter pine, all native to these mountains. Runoff and seepage are caught and measured in tanks set in a concrete tunnel underground. Electric water level transmitters permit the rates of runoff and seepage to be recorded on clock-driven charts. Soil moisture at various depths in the lysimeters is measured frequently with electrical soil moisture instruments.[2] The measurements make it possible to determine water movement into and through the soil as well as evaporative losses from the soil and plants growing in the lysimeters.

To study effects of unnatural soil drainage and restricted root development upon the growth of plants and their use of water in the large "confined" lysimeters, additional records of surface runoff and soil moisture are obtained from five "unconfined" lysimeters. The latter consist of pits 17-1/2 feet square and 7 feet deep, filled with lysimeter soil and planted to five of the species growing in the "confined" lysimeters.

7. Physical Features--Inventories and maps have been prepared of the vegetation, soil, geology, and topography of the Forest. Analysis of streamflow and erosion data for each of the Forest watersheds is evaluating the influence of these physical features, and the climate, upon waterflow and soil movement.

Study of Watershed Management

Studies of watershed management include tests of the following improvement measures:

2/ The fiberglas electrical soil-moisture instrument, developed on the San Dimas Forest, consists of a soil unit buried permanently at the point where moisture measurement is required, and a portable meter to measure electrical resistances of elements within the soil unit. Soil moisture and temperature are determined from these measurements.

1. Changes in Watershed Vegetation--Studies of rainfall disposition and soil movement on slopes under several types of vegetation have been started on the runoff plots. Behavior of the Bell and Fern small watersheds is being observed for a period of years, after which the vegetation on some of them will be changed. Measurements of water yield, flood runoff, and soil movement from the treated watersheds will then be compared with similar measurements made on the watersheds left undisturbed. Vegetation on the Bell watersheds has not been burned since 1919. The Fern watersheds had been unburned for more than 50 years prior to 1938 when a fire swept over this area. Records obtained before and after this accidental treatment showed that storm runoff and erosion were increased greatly for three years after the fire. Another wildfire in 1953 burned over the upper one-third of Wolfskill Canyon (Intermediate watershed I), which has an area of 1,525 acres. The vegetation on this watershed had not been damaged for at least 50 years prior to the 1953 fire. Rainfall and streamflow records obtained from Wolfskill Canyon and other watersheds on the San Dimas Forest for 17 years before the fire were compared with similar records obtained after the fire. These records indicate that the debris-laden peak flow from Wolfskill Canyon during the first large post-fire storm of approximately 6 inches rainfall was more than 100 times as great as would have been expected had the watershed not been partially burned.

2. Management of Stream Bottom Vegetation--It is known that alders, willows, sycamores, and other plants found in stream channels use much water. Complete removal of this vegetation would eliminate water use by the plants, but the loss of shade would increase evaporation from the water and soil. Studies are to be made to determine the species and amount of vegetation that will result in the minimum loss of water from stream bottoms and still provide bank protection during high flows. Some of the studies in this investigation will be conducted in lysimeters. Others will require altering the vegetation in stream channels where records of streamflow can be compared for periods before and after treatment.

3. Engineering Improvements--Studies are to be made of the effects of small dams and retaining walls built in stream channels on total streamflow yield and flood peaks, as well as the stability of soil and rock material in the channels and on adjacent slopes. Effects of the engineering improvements can be determined by comparing hydrologic records from treated and untreated watersheds before and after the improvements are made.

Corollary Watershed Research

Other Forest Service watershed studies have been completed or are in progress elsewhere in southern California. Among the completed studies are: (1) erosion control methods for mountain roads, (2) the "first aid" seeding of burned watersheds, and (3) an appraisal of flood and erosion damages resulting from watershed fires. Now in progress are studies of soil movement on watershed slopes and of vegetation treatment methods designed to reduce this movement. These studies are being carried on in cooperation with the Angeles National Forest on field plots in the Los Angeles River watershed.

THE SAN DIMAS EXPERIMENTAL FOREST

Watershed Areas

Watershed	Drainage area Square miles	Acres	Range in elevation
		MAJOR	
San Dimas	15.75	10,080	1500-5500
Big Dalton	4.46	2,855	1700-3500
		INTERMEDIATE	
San Dimas			
I Wolfskill	2.39	1,530	1700-5200
II Fern	2.14	1,370	2600-5500
III Upper East Fork	2.14	1,370	2600-5200
IV East Fork	5.48	3,510	1900-5500
V North Fork	4.23	2,710	1900-4500
VI Main Fork	13.14	8,410	1600-5500
VII West Fork	1.72	1,100	1600-3100
Total XII (San Dimas)	15.75	10,080	
Dalton			
VIII Bell	1.36	870	1900-3500
IX Volfe	1.16	740	1900-3500
X Monroe	1.37	875	1800-3400
Total XI (Dalton)	4.46	2,855	
		SMALL	
Bell			
No. 1	0.121	77	2500-3400
No. 2	0.158	100	2500-3500
No. 3	0.097	62	2500-3400
No. 4	0.058	37	2500-3100
Total	0.434	276	
Fern			
No. 1	0.055	35	4500-5400
No. 2	0.063	40	4500-5400
No. 3	0.084	53	4500-5400
Total	0.202	128	